NUMERICAL STUDY ON SHEAR STRENGTHENING OF REINFORCED CONCRETE (RC) DEEP BEAMS WITH AND WITHOUT STIRRUPS USING NEAR-SURFACE MOUNTED FRP BARS

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A thesis submitted in

fulfillment of the requirement for the award of the

Doctor of Philosophy

Faculty of Civil Engineering and Built Environment
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NOVEMBER 2020

DEDICATION

To the memory of my mother, my brother, my brothers and all people that help and supported me. To my beloved father for his constant, unconditional love during all my life. Also, to my ever-supporting supervisor Prof. Ir. Dr. Abdul Aziz Bin Abdul Samad

ACKNOWLEDGEMENT

All praises and thanks are to ALMIGHTY ALLAH: the most beneficent and most merciful for blessing me health, wealth power and wisdom to accomplish this milestone in my life. May ALLAH SWT in HIS mercy to make my research work beneficial to other researchers in this field. It was impossible to achieve this milestone without the blessings of ALLAH ALMIGHTY, HIS PROPHET (PBUH) and the support of many peoples. Among them, the first and foremost is my supervisor Prof. Ir. Dr. Abdul Aziz bin Abdul Samad who really inspired and guided me throughout this whole period of my research work; I really would like to many thanks to him and no any words can express my feelings about his profound gratitude I am grateful to him for providing such wonderful support to my postgraduate career. I would also thanks to my Co-Supervisors. Prof. Dr. Noridah Mohamad and Dr. Goh Wan Inn for their support and direction throughout the entire journey of my research work. Their technical guidance helped me to furnish my thesis and for that I will be always thankful to them.

Furthermore, I would also like to thank my Parents and whole family members for Love, Kindness and Support. Their constant moral support, remarkable backing and prayers have endowed me to accomplish this thesis. In the end; many thanks to Faculty Staff and Technician of FKAAB, UTHM and my friends for their valuable time and recommendations.

ABSTRACT

Near surface mounted (NSM) technique is an emerging technique for increasing the strength of reinforced concrete (RC) members. It is applied to strengthen or repair RC members. Fibre reinforced polymers (FRP) bars are commonly used through the NSM technique to strengthen RC members. However, limited studies on NSM strengthening using FRP bars on RC deep beams are available. In this research, a numerical investigation was carried out on RC deep beams strengthened in shear with NSM-FRP bars using the ABAQUS FEA version 2017. Two studies were chosen for validation purposes. The first study consist of two control deep beams modelled with and without steel stirrups and fourteen deep beams strengthened using NSM-CFRP bars with and without steel stirrups with varying parameters of CFRP bars in four groups were strengthened or repaired using the NSM-CFRP bar technique and tested by varying two criteria and namely, spacings of 100 mm and 150 mm at orientations of 0°/90° and 45°/135°. The second study involves three RC deep beams, namely one control beam and two strengthened deep beams with NSM-CFRP bars modelled without stirrups oriented at 45°/135° with spacings of 100 mm and 150 mm. After validation, it was observed that the maximum difference in shear load was +14% between FEA and experimental observations. A parametric study was carried out for thirty RC deep beams strengthened with NSM FRP bars to investigate the FRP bars involving type, diameter, orientation and spacing was also carried out. CFRP bars were most effective as they achieved a maximum improvement in shear strength of +109 %. Combination of 9 mm diameter, 45°/135° inclination angle and 75 mm spacing provides optimum improves of +149%, +163 % and +134%, respectively. Later analytical study was conducted by using parametric study results to develop an empirical equation for predicting the shear contribution by FRP bars through the NSM-FRP bar technique (V_f).

ABSTRAK

Teknik Pemasangan Permukaan (NSM) adalah teknik untuk meningkatkan kekuatan anggota konkrit bertetulang (RC). Disamping itu, teknik ini juga boleh digunakan untuk mengukuh atau membaikpulih anggota RC. Kebiasaannya teknik NSM akan di bina bersama bar polimer bertetulang gentian (FRP) sebagai bahan untuk mengukuh anggota RC. Walau bagaimanapun, kajian mengenai pengukuhan rasuk dalam RC melalui teknik NSM dengan bar FRP (NSM-FRP) adalah terhad. Dalam penyelidikan pengukuhan ricihan rasuk dalam RC dengan teknik NSM-FRP bar, kajian kaedah berangka melalui perisian ABAQUS FEA versi 2017 telah dijalankan. Untuk tujuan pengesahan kajian berangka ini, pemilihan terhadap dua kajian yang lepas telah dilaksanakan. Kajian pertama terdiri daripada dua rasuk kawalan masing-masing dengan perangkai ricih dan tanpa perangkai ricih telah di bangunkan.. Disamping itu, eMPat belas rasuk dalam RC dengan perangkai rich dan tanpa perangkai ricih yang telah di kukuhkan dengan teknik NSM bersama parameter CFRP bar yang berbeza telah di bangunakan dan di asingkan dalam eMPat kumpulan terdiri dari rasuk dalam yang telah di kukuh atau di baikpulih menggunakan teknik NSM-CFRP bar dengan dua kriteria iaitu perangkai ricih pada jarak 100 mm dan 150 mm, dan perangkai ricih pada orientasi 0°/90° dan 45°/135°. Kajian kedua melibatkan tiga rasuk dalam RC iaitu satu rasuk kawalan dan dua rasuk dalam tanpa perangkai ricih yang telah diperkukuh dengan teknik NSM-CFRP bar berorientasi pada 45°/135° dengan jarak 100 mm dan 150 mm. Selepas pengesahan antara kajian berangka dan pemilihan dua kajian yang lepas dijalankan, perbezaan maksimum beban ricih yang diperhatikan adalah sebanyak +14%. Kajian parametrik bar FRP pelbagai jenis, diameter, orientasi dan jarak juga telah dilakukan. Hasil kajian parametrik telah menunjukan jenis CFRP merupakan bar paling berkesan apabila mencapai peningkatan maksimum daya ricih sebanyak +109%. Mana kala gabungan diameter 9 mm, sudut orientasi bar 45°/135° dan jarak pada 75 mm memberikan peningkatan optimum masing-masing pada + 149%, +163% dan +134%. Akhirnya, melalui kajian analitik satu persamaan empirikal yang

meramalkan sumbangan daya ricih bar FRP melalui teknik NSM-FRP (V_f) telah berjaya dibangunakan.

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